

Low-temperature growth of GaInNAs/GaAs quantum wells for 1.3- μ m lasers using metal-organic vapor-phase epitaxy

G. Plaine^{*a}, C. Asplund^a, P. Sundgren^a, S. Mogg^a and M. Hammar^{a,b}

^aDepartment of Electronics, Royal Institute of Technology, Electrum 229, S-16440 Kista, Sweden

^bMitel Semiconductor AB, Box 520, S-17526 Järfälla, Sweden

The growth and optimization of GaInNAs/GaAs quantum wells has been a subject of intense research during recent years. These efforts are mainly motivated from the possibility of realizing 1.3-1.55 μ m diode lasers on GaAs substrates, opening up a pathway for the development of long-wavelength vertical-cavity lasers (VCLs) as well as low-cost edge-emitting lasers with improved temperature-performance as compared to the InP-based technology. So far, the most promising results have been obtained using molecular beam epitaxy (MBE), by which both low-threshold edge-emitting lasers and 1.3- μ m VCLs have been demonstrated [1]. On the other hand, materials grown by metal-organic vapor-phase epitaxy (MOVPE) still appear to lag a step behind, generally resulting in higher threshold currents and broader photoluminescence (PL) emission characteristics, although some promising results recently have been reported also in this case [2]. In the present study, GaInNAs QWs have been grown by MOVPE using a systematic variation of growth parameters in the very low temperature regime. It is demonstrated that good material quality can be obtained at temperatures as low as 475-505°C in combination with very low growth rates. However, a complex relation between growth parameters, PL intensity, PL linewidth and broad-area (BA) laser performance has to be considered. We also note and discuss a strong interplay between the different growth parameters that significantly complicates the optimization process, e.g., highlighting the importance of gas-phase pre-reactions.

GaInNAs and InGaAs/GaAs QW structures were grown on (001) oriented GaAs substrates by low-pressure (100mbar) MOVPE using DMHy, TEGa, TMIn, and TBAs as precursors at growth temperatures and growth rates of 475-505°C and 0.03 nm/s, respectively. Table 1 summarizes the different structures and corresponding PL and BA laser results. The PL test structures comprise a single QW embedded under a 100 nm GaAs cap layer and is annealed for 10 min at the growth temperature of the BA laser AlGaAs claddings (670°C). BA lasers with 50 μ m stripe widths and different lengths were measured under pulsed conditions at heat sink temperatures between 10 and 80°C.

Figure 1 shows the relation between growth temperature and PL FWHM for 1.3- μ m SQWs. While the PL peak intensity in this interval decreases by more than a factor of two, the PL FWHM and BA laser performance were found to improve with increasing temperature. This indicates that the FWHM is the more relevant PL optimization parameter. Figure 2 compares threshold current densities for 1.3- μ m BA lasers grown at two different temperatures with those for 1.2- μ m InGaAs lasers. The GaInNAs lasers grown at the higher temperature shows an improved threshold current density of 1.2 kA/cm² (0.8 kA/cm² when extrapolated to infinite length) and a slope efficiency as high as 0.25 W/A for a length of 1400 μ m. These lasers exhibit a T_0 value of 80 K.

1. B. Borchert et al., IEEE Photon. Technol. Lett., 12 (6), 597 (2000); K.D. Choquette et al., Electron. Lett., 36 (16), 1388 (2000).
2. M. Kawaguchi et al., Electron. Lett., 36 (21), 1776 (2000); S. Sato, Jpn. J. Appl. Phys., 39 (Part 1, No. 6A), 3403 (2000); F. Höhnsdorf et al., Electron. Lett., 35 (7), 571 (1999).

* Corresponding author. Email: plaine@ele.kth.se

Table 1. PL and BA laser characteristics of laser structures emitting at 1.2-1.3 μm

SQW Structure $\text{GaIn}_x\text{N}_y\text{As}$			$T_{\text{grow th}}$ $^{\circ}\text{C}$	PL		BA laser length (μm)	λ (nm)	J_{th} (kA/cm^2)	Slope eff. (W/A)	T_0 (10-80 $^{\circ}\text{C}$) (K)
x	y	nm		Intensity (a.u.)	FWHM (meV)					
0.39	0	7.2	520	5700	30	800	1200	0.3	0.25	104
0.35	0.002	6.8	490	730	35	800	1200	1.9	0.2	77*
0.37	0.007	6.4	495	4	48	800	1270	1.7	0.25	80
0.37	0.006	7.2	475	13	55	800	1291	3.3	0.20	85*

* 10 – 50 $^{\circ}\text{C}$

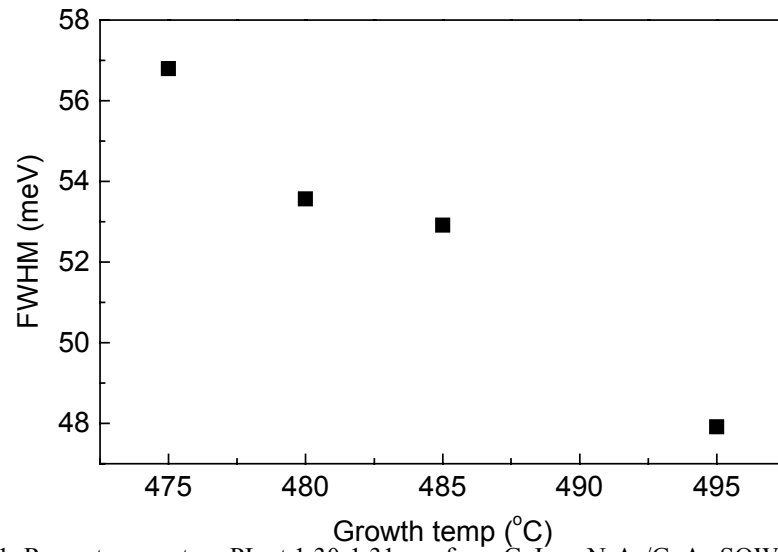


Fig. 1. Room temperature PL at 1.30-1.31 μm from $\text{GaIn}_{0.37}\text{N}_y\text{As}/\text{GaAs}$ SQWs of similar N content ($y=0.006 - 0.007$) and thickness (6.4 - 7.2 nm).

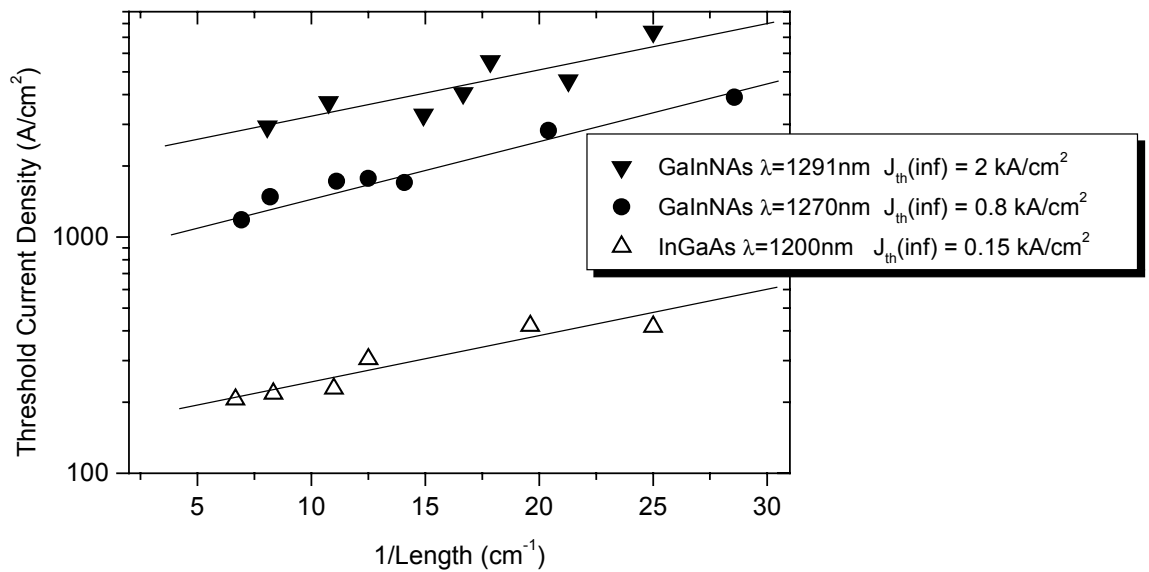


Fig. 2. BA laser threshold current densities as a function of inverse cavity length.